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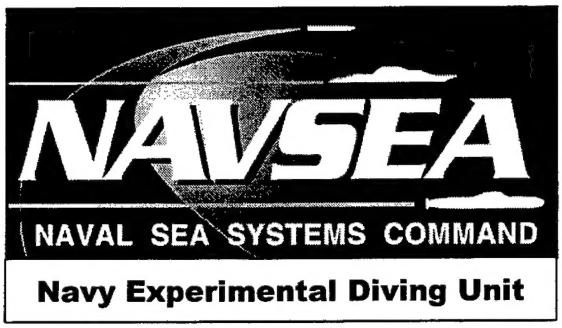

EVALUATION OF SEAQUEST "BLACK DIAMOND" BUOYANCY COMPENSATOR

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19. ABSTRACT: **NEDU was tasked to conduct a survey of commercially available buoyancy compensators (BCs), and perform testing to determine which BC perform satisfactorily. Buoyancy compensator evaluation was conducted in three phases. Phase I, receipt inspection of the buoyancy compensator, technical review of the manufacturer supplied documentation (instructions / repair manuals), diver orientation, and Test Pool Evaluation (BC surface floating attitudes if used as a Life Jacket). No failure mode analysis was conducted. Phase II consisted of buoyancy / lift capacity testing in the OSF at 190 fsw. Phase III consisted of manned dives in the Gulf of Mexico to test diver buoyancy control and operational characteristics.**

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INTRODUCTION

Navy Experimental Diving Unit (NEDU) is tasked[1] to conduct surveys of commercially available buoyancy compensators (BCs), and perform testing to determine which BCs perform satisfactorily in accordance with references (2) and (3). All buoyancy compensators that meet the above requirements will be candidates for recommendation to the Authorized for Navy Use (ANU) list. The purpose of this technical report is to determine if the Seaquest "Black Diamond" buoyancy compensator meets those requirements.

METHODS

GENERAL

Each BC was tested and evaluated in three different environments Phase I (Bench Test), Phase II Controlled Environment (Test Pool/Ocean Simulation Facility (OSF)), and Phase III (Open Ocean Diving). While bench testing, each BC was evaluated by two qualified U.S. Navy divers for completeness and adequacy of maintenance manuals and technical documentation, skill level required to perform routine repair and maintenance, operation of the integrated weight belt and the operation of all BC components. In a controlled environment, each BC was tested and evaluated for buoyancy and lift capability. While performing open water dives, each BC was used and evaluated by eleven qualified U.S. Navy divers in both single and double SCUBA tank configurations to a minimum of 30 fsw (9.4 msw). The conversion for msw is in accordance with reference (3).

EXPERIMENTAL DESIGN AND ANALYSIS

All BCs tested were off the shelf items; three sizes were tested, (i.e., medium, large and X-large). The Task Leader or assigned representative was present during the set-up and post-dive procedures on all BCs.

<u>Phase I testing:</u>

- Each model BC was evaluated by two qualified U.S. Navy divers for ease of operation and maintenance procedures.
- Average price, from five different suppliers was acquired.

Specific comments from evaluators were compiled and documented.

<u>Phase II testing:</u>

- All different size BC were tested to 190 fsw (59.4 msw) utilizing the OSF. Each BC was fully inflated three times in both single and twin configurations, recording the average lift capacity.

Phase III testing:

- All different size BCs were evaluated during open water dives. A series of evaluation dives consisted of eleven man-dives per BC, per tank configuration (i.e., single and twin). All open water dives were conducted to a minimum depth of 30 fsw. Divers completed a human factor questionnaire after each dive. A set of descriptive statistics of the responses and specific comments were complied.

EQUIPMENT AND INSTRUMENTATION

No special or proprietary tools were required to perform routine maintenance or repair on the BCs.

a. Phase I: During bench testing, the following equipment was used:
   (1) Fully charged SCUBA bottle and an approved regulator (used to supply low-pressure air to perform equipment checks)
   (2) Manufacturer's instructions and maintenance manual
   (3) Miscellaneous hand tools and adapter fittings
   (4) Weights (soft or molded)

b. Phase II: During OSF testing the following equipment was used:
   (1) Calibrated spring scale (Model #895, Viking Scale, Shubuta, MS), 0 to 50 pounds (0 to 22.68 kg)
   (2) Lanyards, spinnaker shackles, and weight as appropriate to anchor BCs to deck in wet chamber
   (3) Fully charged SCUBA bottle and an approved regulator (used to supply low-pressure air)
   (4) Personnel as required
   (5) Weights

c. Phase III: During at sea testing, the following equipment was used:
   (1) Fully charged SCUBA bottle, approved regulator and all other personnel diving equipment needed to perform a SCUBA dive
   (2) Personnel as required
   (3) At sea diving platform

PROCEDURES

BC evaluation was conducted in three phases: (1) receipt inspection and technical review of manufacturer supplied documentation, (2) OSF wet chamber evaluation (buoyancy/lift capacity at 190 fsw (3) open water dives to test buoyancy control and operational characteristics.

a. Phase I testing began with a review of the following:

(1) Completeness and adequacy of the maintenance manuals and technical documentation
(2) Requirements for special or proprietary tools
(3) Skill level required to perform routine repair and maintenance
(4) Operation of integrated weight system
(5) Operation and activation of all BC components
(6) Ease of assembly from single tank configuration to twin tank configuration
(7) Unit price

A technical documentation and operational function worksheet was completed by each qualified diver assigned, and returned to the Task Leader.

b. Phase II Testing: Buoyancy/lift capacities of the units were tested in the OSF wet chamber at depths of 190 fsw. All divers participating in the study were required to familiarize themselves with the contents of the user's manual, to include location of controls on the BC and donning procedures.

A calibrated spring (Model #895, Viking Scale, Shubuta, MS) was attached to the deck grating of the OSF to measure buoyancy. Each BC tested was attached to the scale and tested in the OSF, pressurized to 190 fsw. The buoyancy was measured and documented; at a minimum, each BC was required to provide 10 lbs. of positive lift as outlined in reference (2). The BC was also tested for leaks at depth.

c. Phase III Testing: Manned open water dives were conducted to a minimum depth of 30 fsw to determine each BC's swim characteristics. Results were documented using a diver's questionnaire.

RESULTS

PHASE I

The inspection of the manufacturer's supplied documentation on the use, service, parts, technical aspects and exploded views/diagrams was unsatisfactory. Documentation also failed to include a parts list or technical specifications within the supplied buoyancy compensator manual, but are available from the manufacturer upon request. There were no requirements for special or proprietary tools needed. Skill level required to perform routine maintenance should be at least a second class diver or above. The integrated weight system weights were secure and easy to operate the release mechanism. The operation and activation of all BC components were easy to operate. There were no problems assembling the single tank configuration to the twin tank configuration, but tools were needed to perform this task.

The average manufacturer's suggested price per unit (Small – X-Large) is $545.

PHASE II

The average of all sizes of the "Black Diamond" in the single tank configuration was 29.7 lbf of positive lift at 190 fsw (see Table 1). The measured buoyancy of the "Black Diamond" BC was approximately 40.5% less than the 50 lbf (all bladder sizes are listed as 50 lbf.) quoted by the manufacturer. However, that difference might have been due to differing test conditions, procedures, or depth. In the twin tank configuration the three sizes of the "Black Diamond" averaged 29.3 lbf of positive lift at 190 fsw (see Table 1). The measured buoyancy of the "Black Diamond" BC was approximately 41.3% less than the 50 lbf (all bladder sizes are listed as 50 lbf.) quoted by the manufacturer. Again the difference might have been due to differing test conditions, procedures, or depth.

PHASE III

During the manned evaluation of the Seaquest "Black Diamond," 21 divers tested the buoyancy compensator in both tank configurations to depths ranges from 30 to 130 fsw. On a scale of 1 – 7 (4.0 being the minimum mark for an overall acceptable score). This BC scored a rating of 5.02 in the single tank configuration and 5.31 in the twin tank configuration

CONCLUSIONS

During testing, two major items of note were encountered. First, in accordance with the manufacturer's technical manual and Maintenance Requirement Card (MRC) MIP 5921/023 R-1, the cylinder band strap must be wet prior to installation of the tank (single configuration). If this was not done, the bottle had a tendency to slip down and out of the BC, which could lead to the loss of the diver's air supply.

The second item noted was the difficulty shifting the BC from single tank configuration to twin tank configuration. In order to install the twin tank configuration, tools and a special banding kit are needed. Once the BC is in the twin tank configuration it requires tools to remove the tanks from the BC for charging of air or any other necessary maintenance.

The buoyancy compensator "Black Diamond" has an integrated weight belt system that can be removed and ditched from the buoyancy compensator by the diver in case of emergency[4]. Either one or both sides of the system can be ditched, to regain proper buoyancy control. It is suggested that only one side is dumped at a time, this will allow the diver to see if proper buoyancy has been regained. If not, the other side may be ditched. This system is easy to use and easy to reinstall onto the buoyancy compensator. The weight module pockets are designed to hold a maximum of 16 lbs. of molded or soft weights in each pocket for a total onboard weight capacity of 32 lbs.

RECOMMENDATIONS

Based on the testing and evaluation in accordance with reference (3) and reported in Tables (1) and (2), we recommend that the Seaquest Model name "Black Diamond" (P/N: Small, 3110-91, Medium 3110-92, Medium Large 3110-93, Large 3110-94, X-Large 3110-95) be authorized for continued Navy use. Prior to each diving day, PMS MIP 5921/023 R-1 must be completed. No surface floating attitude testing was conducted as per manufacturer supplied documentation, therefore we do not recommend this buoyancy compensator be used as a life preserver.

Table 1. Seaquest "Black Diamond" Buoyancy Compensator Pull Test Data Sheet

Seaquest "Black Diamond" Single Tank Configuration					
NO.	NOMENCLATURE	BC SIZE	BUOYANCY (LBF)	DEPTH	INFLATION METHOD
1	Seaquest "Black Diamond"	M	29	190 FSW	LP WHIP FROM SCUBA BOTTLE
2	Seaquest "Black Diamond"	L	31	190 FSW	LP WHIP FROM SCUBA BOTTLE
3	Seaquest "Black Diamond"	XL	29	190 FSW	LP WHIP FROM SCUBA BOTTLE
	Average Buoyancy		29.7		
Seaquest "Black Diamond" Double Tank Configuration					
NO.	NOMENCLATURE	BC SIZE	BUOYANCY (LBF)	DEPTH	INFLATION METHOD
1	Seaquest "Black Diamond"	M	28	190 FSW	LP WHIP FROM SCUBA BOTTLE
2	Seaquest "Black Diamond"	L	30	190 FSW	LP WHIP FROM SCUBA BOTTLE
3	Seaquest "Black Diamond"	XL	29	190 FSW	LP WHIP FROM SCUBA BOTTLE
	Average Buoyancy		29.3		

Table 1. Each size BC was tested to 190 fsw (59.4 msw) utilizing the OSF. Each BC was fully inflated three times in both single and twin configurations. Recording the average lift capacity.

Table 2 (cont.) Human Factors Evaluation of the Seaquest "Black Diamond" Buoyancy Comensator in Single and Double Tank Configuration

Seaquest "Black Diamond" Single Tank Configuration

QUESTIONNAIRE #	#18 Over All Rating	#19 Operating Controls	AVERAGE	#20 Wearing Gloves	#21 Water Drag	#22 Were You Comfortable With BC	#23 To Many Buckles and Straps	#24 Can 2nd DV Operate	#25 BC of Choice	#26 Asset to Fleet
1	5	5	5.00	Y	N	Y	N	Y	Y	N
2	5	5	4.89	Y	N	Y	N	Y	N	N
3	3	4	3.82	Y	Y	Y	Y	N	N	N
4	5	5	4.73	Y	Y	Y	N	Y	Y	Y
5	5	5	5.27	Y	N	Y	N	Y	Y	Y
6	5	4	4.73	Y	N	Y	N	Y	Y	Y
7	6	6	5.80	Y	N	Y	Y	Y	Y	Y
8	3	4	3.91	Y	N	N	N	Y	N	N
9	5	6	4.50	Y	Y	Y	N	Y	Y	Y
10	6	6	5.82	Y	Y	Y	Y	Y	Y	Y
11	6	7	6.73	Y	N	Y	N	Y	Y	Y
QUESTION AVERAGE	4.91	5.18	5.02	11 out of 11	4 out of 11	10 out of 11	3 out of 11	10 of 11	8 of 11	7 out of 11
				YES	YES	YES	YES	YES	YES	YES
	Overall Average		5.02							

Seaquest "Black Diamond" Double Tank Configuration

QUESTIONNAIRE #	#18 Over All Rating	#19 Operating Controls	AVERAGE	#20 Wearing Gloves	#21 Water Drag	#22 Were You Comfortable With BC	#23 To Many Buckles and Straps	#24 Can 2nd DV Operate	#25 BC of Choice	#26 Asset to Fleet
1	3	4	3.91	Y	Y	N	Y	N	N	N
2	6	6	6.00	Y	N	Y	N	Y	Y	Y
3	6	6	5.82	Y	Y	Y	N	Y	Y	Y
4	4	4	5.09	Y	N	Y	Y	Y	N	N
5	3	4	3.91	Y	N	N	N	N	N	N
6	6	6	5.82	Y	Y	Y	N	Y	Y	Y
7	5	6	4.91	Y	N	Y	N	Y	N	N
8	6	5	5.45	Y	N	Y	N	Y	Y	Y
9	5	7	5.64	Y	N	Y	N	Y	Y	Y
10	6	5	5.18	Y	N	Y	N	Y	Y	Y
11	6	7	6.73	Y	N	Y	N	Y	Y	Y
QUESTION AVERAGE	5.09	5.45	5.31	11 out of 11	3 out of 11	9 out of 11	2 out of 11	9 out of 11	7 out of 11	7 out of 11
				YES	YES	YES	YES	YES	YES	YES
	Overall Average		5.31							

Table 2. A series of evaluation dives will consist of ten man dives per BC, per tank configuration. All open water dives were conducted at a minimum depth of 30 fsw (9.4 msw). Divers completed a human factors questionaire after each dive. A set of descriptive statistics of the responses and specific comments were complied. The BCs is scored on a scale of 1 – 7 scale (4.0 being the minimum mark for an overall acceptable score) (1 = poor, 4 = adequate, 7 = excellent).

REFERENCES

1. Command Naval Sea Systems Command, Task Assignment 98-10, *Commercial Diving Equipment Test and Evaluation*, Dec 97.
2. C. J. Zanoni, *Procedure for the Evaluation of Commercially Available Buoyancy Compensator's (Unmanned/Manned),* NEDU TP00-10, Navy Experimental Diving Unit, September 2000.
3. Naval Sea Systems Command, *U.S. Navy Diving Manual, Vol. #5*, Rev. 4, NAVSEA SS521-AG-PRO-010, 20 Jan 99.
4. NAVSEA Supervisor of Salvage and Diving, Director of Ocean Engineering, *Diving Equipment Authorized for Navy Use*, 00C/3112 ltr of 15 May 97.